Advanced Concepts in Lumbar Degenerative Disk Disease

João Luiz Pinheiro-Franco
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Editors

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This book is dedicated to the neurosurgeon who inspired my career: my father, Luiz Fernando Pinheiro-Franco, who is fond of saying Natura non facit saltus (Latin for "Nature (Life) *makes no leap").*

João Luiz Pinheiro-Franco

We also dedicate this book to our patients and our colleagues. Without all of them, this book would not have been possible.

João Luiz Pinheiro-Franco
Alexander R. Vaccaro
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Preface

After my graduation in neurosurgery, I had the unexpected privilege to immerse myself in 4 years of clinical and research fellowships, working with or simply observing the clinical and surgical techniques of several world-renowned experts in treating spinal diseases. Being far from my native country, I had at times longed for family, friends, and colleagues, yet at the same time, the experience thrust me into the emerging field of globalized spinal surgery. It was during this time that I first came in direct contact with incredibly interesting people, all of us breaking the barriers of language to make sense of many different concepts, with different ideas bubbling forth from so many gifted minds. Although there was tremendous diversity in our avenues of thought, everyone was driven by the common pursuit of great results.

These were my earliest impressions as a "global spinal surgeon." Reflecting on that time, I can say undoubtedly that the single unifying element of that great diversity in talent and ideas was an underlying modus operandi dedicated to the common goal of serving the well-being of patients suffering from lower back ailments. It was during this period when I conceived the notion of a "puzzle theory" of knowledge: different pieces of a puzzle falling into place. At first, only a few scattered pieces seemed to make sense, others less so or not at all. However, gradually, as more pieces came together, a clear image steadily emerged, more tangible, more solid, and more understandable.

I share this experience with you to offer insight into the origin of this book. In some respects, it is a tribute to the people from around the world who contributed with total mind and dedication to what had once seemed the serendipity of solving the "puzzle" of what today we call *lumbar degenerative disk disease*. This is the wellspring we present to you as *Advanced Concepts in Lumbar Degenerative Disk Disease*.

It is a great honor to share with you the insights and rigor of my coeditors, Dr. Alexander R. Vaccaro, Dr. Edward C. Benzel, and Dr. H. Michael Mayer. They are perhaps the three greatest minds I have ever had the opportunity to work with. Above all, they each possess a particular magnetism and charisma that electrify audiences with their knowledge in a way that influences people to make a difference in the world. They themselves have made many great differences, yet they are modest and sincere in their relationships with both colleagues and patients. I thank them dearly for the time invested and the enormous knowledge shared in the chapters of this book.

Similarly, I extend my thanks to everyone who participated in the production of the various chapters in this book. This dedicated group of men and women from all over the world helped gather a variety of concepts into an extensive knowledge base for our field. These contributors include internationally recognized thinkers of new concepts, creators of innovative techniques and novel instruments, and courageous voices of provocative new philosophies—all at the vanguard of lumbar degenerative disk disease.

Advanced Concepts in Lumbar Degenerative Disk Disease was written and designed for spinal surgeons, neurosurgeons, and orthopedic surgeons: those who are new to the field as well as those who are more seasoned professionals.

Part I of the book begins by laying out the foundations of bipedalism and the importance of the verticalization of the spine, that is, the alignment of the intervertebral disks to bear the weight and function of the upper body. The opening chapter was written by the internationally award-winning French paleoanthropologist Yves Coppens, who also gave his name to the asteroid. Then, Gusmão et al., in fine detail, take the reader through the evolution of the concept of sciatica to what is known today as lumbar disk degeneration. Part I continues with an award-winning German scientist's discussion of the pathophysiologic fundamentals of disk degeneration and the degenerative cascade. Epidemiology is treated by the late Pierre Kehrli, with the section on genetics perhaps deserving the most attention. This subject is examined further in the chapter by Cheung et al.

Part II opens with contemporary advancements in spinal imaging, with a subsequent chapter by Dr. Michael Modic. An experienced team of experts then takes on the controversial theme of diskography.

Part III examines the day-to-day issues faced by surgeons in practice: psychosocial aspects in patient care, work-related issues, costs, outcome measures, and conservative treatments. This section also includes a comprehensive chapter dedicated to facet pain.

Part IV deals with lumbar disk herniation, once disregarded by many surgeons as "just an herniated disk." Here, the subject receives the attention it deserves. This section closes with chapters on scientific considerations, technical operation, and revision surgeries.

Part V focuses on the surgeon's decision-making process in providing individualized care. In detail, it examines when to operate, when to fuse or not to fuse, adjacent disease, biomechanics, techniques to increase lordosis, bone substitutes, the osteoporotic spine, and the advantages of different accesses: frontal, posterior, lateral, transpsoas, and oblique.

Part VI consists of several engaging discussions regarding studies on minimally invasive techniques: intradiscal therapy, endoscopy, spinal injections, use of tubes, disk cell transplantation, and robotic spinal surgery, as well as a comprehensive chapter on the use of spinal injections after spine surgery.

Part VII addresses nonfusion technologies such as disk arthroplasty and dynamic techniques based on pedicle screws and interspinous devices.

Part VIII includes discussions on degenerative scoliosis, the modern concept of sagittal balance of the spine, compensatory mechanisms of sagittal imbalance, and osteotomy techniques.

Finally, in part IX, “Lessons from a Life,” some of the most experienced spine surgeons today share their personal clinical experiences. This is a valuable resource for all surgeons.

This is just a glimpse of what we have included in *Advanced Concepts in Lumbar Degenerative Disk Disease*. I hope you enjoy reading it as much as I have enjoyed bringing it together for you.

São Paulo, Brazil João Luiz Pinheiro-Franco

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Part I

Essentials in Lumbar Degenerative Disk Disease

1 We've Been Standing Up for 10 Million Years

Yves Coppens

1.1 Introduction

Editor's Note In this chapter, Professor Yves Coppens provides an enlightening perspective regarding a field of science that he pioneered. His account, in conversation form, is unique from historical and scientific perspectives.

Dr. João Luiz Pinheiro-Franco has invited me to contribute to this important work on advanced concepts of degenerative lumbar disk disease. As this subject is undoubtedly beyond my field of expertise, he proposed that I elaborate on the developmental factors involved during the human transition from locomoting in quadruped position to the biped upright standing position, which comfortably fits within my academic considerations.

Thusly framed, I have decided to address the history of our human-primate "kinship," that period when Homininae separated themselves from the Paninae, probably for environmental reasons, somewhere in tropical Africa, 10 million years ago.

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Human beings are, obviously, living beings and as such have their place in a taxonomy of their presumed natural relationships: a chronologically ascending and integrative classification, we are all at once a eukaryote, metazoon, chordate, vertebrate, gnathostomata, sarcopterygian, tetrapod, amniote, synapsid, mammal, and primate. And among primates the taxonomy continues: haplorrhine, simiiform, catarrhinian, hominoid, and hominid. At present, in most scientific classifications, Hominidae include Paninae, which are in common terms the pre-chimpanzees and

Editor's Note Professor Yves Coppens, along with Donald Johanson and Maurice Taïeb, discovered the now famous "Lucy," at that time, the oldest bipedal hominid skeleton. The name Lucy was given as reference to the Beatles song, "Lucy in the sky with diamonds," which was popular at the time of their excavations and research. Prof. Coppens was the Chairman of Anthropological Biology in the Natural History Museum (Paris, France, 1969-1983). For 22 years (1983–2005), he served as Chair of Paleoanthropology and Prehistory at the prestigious Collège de France. He is also member of the "Académie des Sciences de l'Institut de France" (since 1983) and member of the National Academy of Medicine (France) since 1991. From 2005, Professor Coppens serves as Emeritus Professor of Paleoanthropology and Prehistory in the Collège de France. The Collège de France was founded in 1530. Its alumni include renowned scientists such as André-Marie Ampère (1824–1836) and Charles-Édward Brown-Séquard (1878–1894), among others. He has discovered tons of fossils of vertebrates and signed or cosigned six new Hominidae. He was nominated Grand Officier de la Légion D'Honneur of France. His name was given to an asteroid (172850 Coppens).

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chimpanzees, and equally include the Homininae, which are the prehumans and humans of today. This leads to the assumption that Paninae and Homininae share a common ancestry.

As it is known that all primates have tropical origin and Paninae stem from African origin, there is the significant probability that this common ancestry and at least their first descendants were tropical and African.

And, in fact, it is only tropical Africa that provided the necessary conditions.

Furthermore, analyses of the great morphological, anatomical, physiological, genetic, molecular, and ethological distances between our "cousins" Paninae and ourselves have allowed us to calculate our last common ancestry to have happened in the upper Miocene, around 10 million years ago, the birth date of our taxonomic subfamily. The location: tropical Africa.

Today, there are three candidates with such an origin and age for this ancestry: *Chororapithecus abyssinicus*, from Ethiopia, 10.7 to 10.1 million years ago; *Nakalipithecus nakayamai*, from Kenya, 9.88 to 9.89 million years ago; and *Samburupithecus kiptalami*, also from Kenya, 9.6 million years ago.

Fossils of these candidates provide an idea of our common ancestor's appearance, but not clear enough to place them before or after the divergence of Paninae/Homininae, raising the dilemma if they were already Paninae (pre-chimpanzee) or Homininae (prehuman) or existing side by side. What is known is that the location was unequivocably a tropical and forestal biotope and that it was at this time that the separation occurred for environmental reasons. This was the departure point for our evolution as a Homininae, our exclusive developmental path.

Over the course of 10 million years, this path has been recorded by genus and species, primarily prehumans from 10 to 1 million years ago and then humans, from 3 million years ago until today and into the future. This trajectory, therefore, implies that the last prehumans were contemporaries of the first humans.

The prehumans are numerous and differentiate widely into 7 genera and 14 species, discovered in South Africa, Malawi, Tanzania, Kenya, Ethiopia, and Chad, and all share tropical origins that are solely African. These specimens also all possessed a static, permanent upright position with a biped and arboreal locomotion initially, then transitioning to be exclusively bipedal. These prehumans also demonstrate a brain in mild expansion and facial feature undergoing a mild reduction with teeth at times under reduction and at other periods under expansion.

1.2 How Did We Become Upright?

The acquisition of an upright posture – the underlying contingency which made it possible for early humans to extend the trunk, pelvis, thigh, and legs – combined with the resulting bipedal locomotion, represents the key transformation point in the history of Homininae, one that gradually and mechanically induced other transformations, in particular changes in the hands and brain, which facilitated consecutively the emergence of tools and consciousness, culture, and society.

In successive order, from an anatomic and as functional as possible perspective, I shall lay out the underlying factors concerning the acquisition of an upright posture in a static condition and the ability to walk upon the hind feet. The following considerations are based upon observations gleaned from different parts of the skeleton of the *Australopithecus afarensis* species.

Observations for body size and body displacement movements were made from a fragmentary skeleton excavated from a field in Ethiopia, AL288,[1] a separate group of bones related to the same species from the same excavation field and 34 footprints from a field in Tanzania; indeed AL288 is the most complete archeological sample set known concerning erect posture acquisition and hind feet locomotion.

[1] AL288 is "Lucy," discovered in 1974 by Yves Coppens. It was, at that time, the oldest bipedal hominid ever discovered, over more than 3 million years old.

1.2.1 Vertebral Column

There are ten artifacts to describe the vertebral column, all from skeleton AL288: seven thoracic vertebrae, two lumbar vertebrae, and one sacrum.

The seven thoracic vertebrae – T2, T6, T7, T8, T10, T11, and T12 – are very similar to their human homologues. On initial observation, they differ only for two main features, moreover without any relationship between them: *Australopithecus afarensis* (*AL288*) vertebrae are significantly smaller in all linear dimensions. However, there is one exception: the sagittal diameter is proportionally very large as it is artificially increased due to a bony arch on the ventral surface of vertebral bodies.

The two lumbar vertebrae – L3 and L4 – are also small in size. Their morphology and the orientation of their different parts make one surmise that the thoracic kyphosis had extended until them. Therefore, it had been more akin to a thoracolumbar kyphosis with a large radius curvature.

Finally, the sacrum, formed by its five fused parts, appears strikingly human, albeit obviously smaller in measurement and proportion. Besides being shallow, it is proportionately extended at its frontal dimension.

Although extremely fragmentary as evidence, this spinal column clearly represents an upright and erect being. Cervical lordosis was highly likely, while thoracic kyphosis was clearly undeniable, appearing only slightly more stretched downward into the lumbar region than ours today. It is appropriate to consider the human variability in this matter: the sagittal angle of its curvature can be estimated to be between 30° and 40°. Lumbosacral lordosis is also present but, however, clearly reduced due to the thoracolumbar stretch. In addition, lordosis is slight, with a curvature of between 40° and 55°. Furthermore, it is quite probable that the spinal cord had had a lower cervical dilation and lower lumbar component (transversal diameter of T2 triangular and large; sagittotransversal index of the L4 vertebral hole quite high).

1.2.2 Pelvis

Half of the pelvis of the AL288 skeleton is very well preserved. The proportions of this pelvis are human-like; however, its anatomy differs in a certain number of particularly interesting features and in their functional consequences, which we shall touch upon briefly.

Firstly, the iliac bones are oriented in a much more frontal coronal plane than in the human pelvis and are clearly wider than human counterparts. Of the ilium, there is a very slight indentation in the internal iliac fossa and is also very wide. The pelvic cavity is broad and also extended thankfully to the important development of the acetabular diameter and the length of the pubis cranial ramus, with its ventrocaudal inclination. The sacrum is, as previously mentioned, also very wide, though short and slightly curved. The sciatic notch is barely marked, and finally, the coxofemoral joints are seemingly undersized. The length of the caudal segment and the short size of the cranial segment confer the ilium-specific longitudinal proportions: a narrow sacral plane and excessively broad iliac plane attenuating to a slender lower extremity.

Furthermore, the ilium presents an iliac crest almost straight in line between the ventrocranial iliac spine (anterior superior iliac spine) and dorsocranial iliac spine (posterior superior iliac spine). The ventrocranial iliac spine is, indeed, distinctively beak shaped, which at this level results in the superposition of the iliac pillar above the iliac spine.

The following discussion involves other segments of the inferior member that cannot be disassociated with the pelvis. The femur is short with a slim and elongated neck. It is obliquely oriented relative to the pelvis, but almost perpendicular to the diaphysis, which is also oblique. The large trochanter is flattened, while the intercondylar fossa is broad and deep. The tibia is short with compact and poorly developed spines possessing asymmetric cavities and a slightly convex external aspect. The foot is short, broad, and flat, with a splayed first radius and stepping onto external support.